

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 12

METER ASSEMBLY AND A-C MEASUREMENTS



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Experiment Lesson 12

PART 1

OBJECT

1. To wire the a-c section of the multimeter.

2. To calibrate the a-c section of the multimeter.

EQUIPMENT NEEDED

Kit 6

Soldering iron and stand

Cloth for cleaning soldering iron

Long-nose pliers

Cutting pliers

Penknife, awl, or scribe

12¼-inch length of solid pushback wire

PREPARATION

1. Unpack the parts in Kit 6 carefully, and check them against the parts listed and pictured on page 2 of Experiment Lesson 11. Return immediately any parts that you find broken or obviously defective, together with the packing slip, to the address given on the packing slip. Put the choke aside for use in future lessons.

2. Clear your workbench or table and arrange your tools for easy use.

3. Make sure that your soldering iron is tinned and cleaned.

4. Look at Fig. 12-1 and 12-2 to see the assembling and wiring that you are going to do in this lesson.

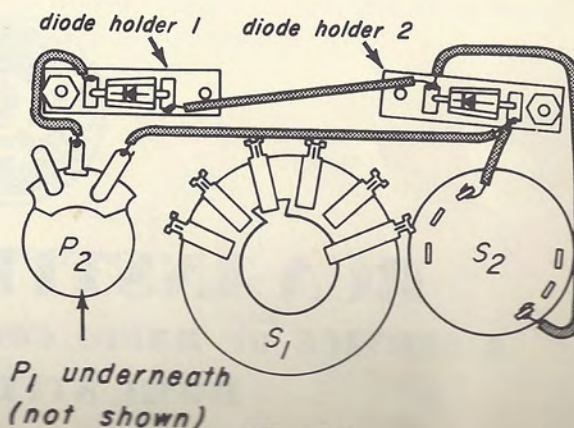
JOB 12-1

To connect the two diode holders together.

Procedure.

Step 1. Examine the two diode holders that came to you in Kit 6. They are exactly alike. Each holder has two clips. Figure 12-3a shows one of the diode holders. The left-hand clip is labelled clip 1, and the right-hand clip is labelled clip 2. In the following steps, you are going to connect clip 1 of one diode holder to clip 2 of the other diode holder.

Step 2. Place the diode holders on your work table as shown in Fig. 12-3b. The diode holder to the left is diode holder 1 and the diode holder to the right is diode holder 2.



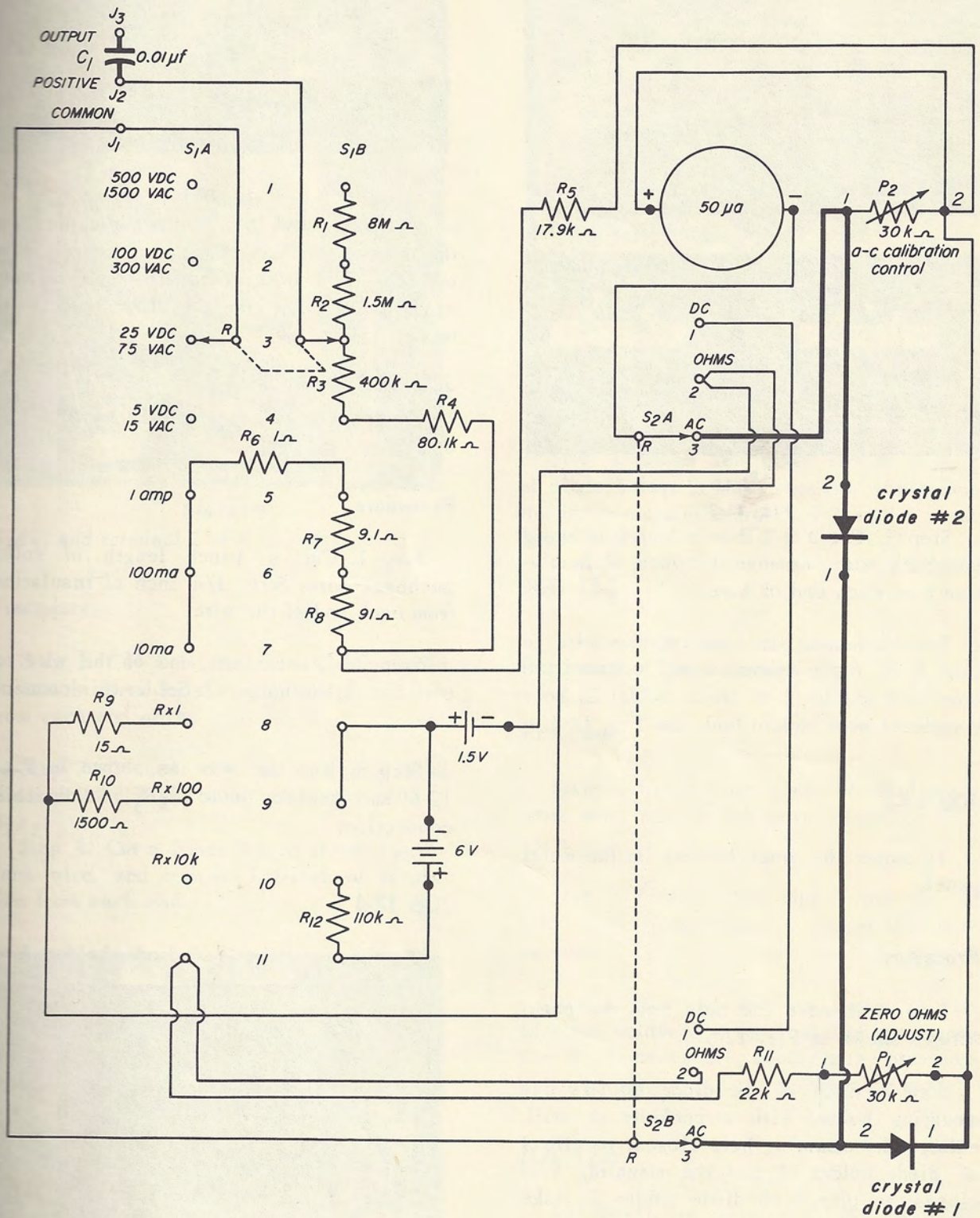
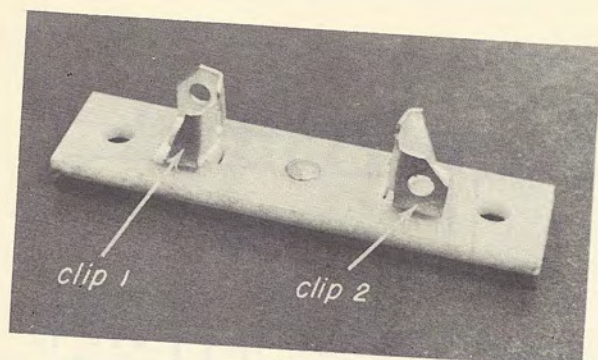
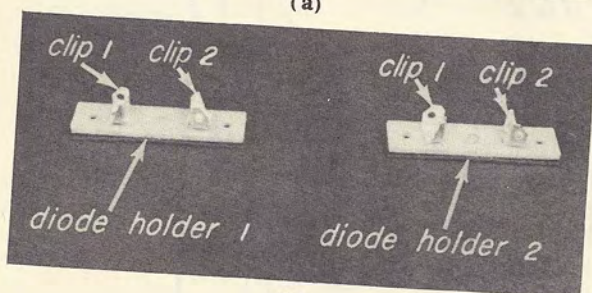


Fig. 12-2



(a)



(b)

Fig. 12-3

Step 3. Cut a 2-1/2-inch length of solid pushback wire. Remove 1/4-inch of insulation from each end of wire.

Step 4. Solder one end of the wire to clip 2 of diode holder 1 and connect the other end to clip 1 of diode holder 2. Your completed work should look like Fig. 12-4.

JOB 12-2

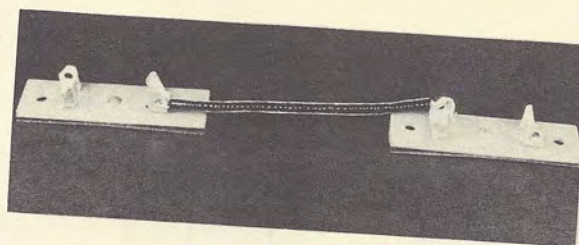
To mount the diode holders on the meter panel.

Procedure.

Step 1. Remove the nuts from the panel screws shown in Fig. 12-5.

Step 2. Each of the diode holders has mounting holds. With a penknife or drill, enlarge the mounting hole closest to clip 1 of diode holder 1 and the mounting hole closest to clip 2 of diode holder 2. Make these holes large enough so that the panel screws will fit through them.

Step 3. Slip diode holder 1 over the panel screw just above potentiometer P_2 and slip diode holder 2 over the panel screw

**Fig. 12-4**

just above switch S_2 . Replace the nuts on the screws and tighten them securely but not too much. If the nuts are tightened too much, they may cause the diode holders to break.

JOB 12-3

To connect clip 1 of diode holder 2 to S_2B_3 .

Procedure.

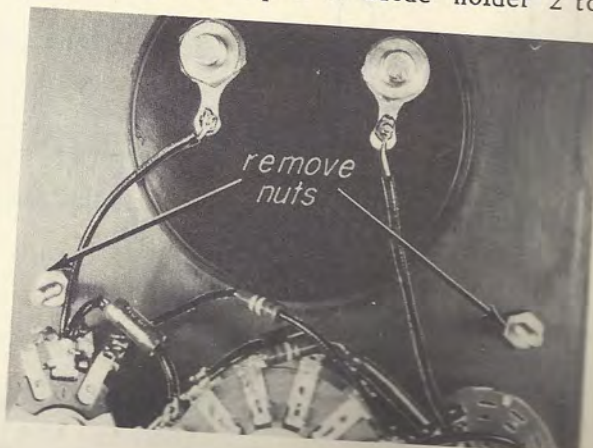
Step 1. Cut a 4-inch length of solid pushback wire. Strip 1/4 inch of insulation from each end of the wire.

Step 2. Connect one end of the wire to clip 1 of diode holder 2. Solder this connection.

Step 3. Run the wire as shown in Fig. 12-6 and connect it to S_2B_3 . Solder this connection.

JOB 12-4

To connect clip 2 of diode holder 2 to

**Fig. 12-5**

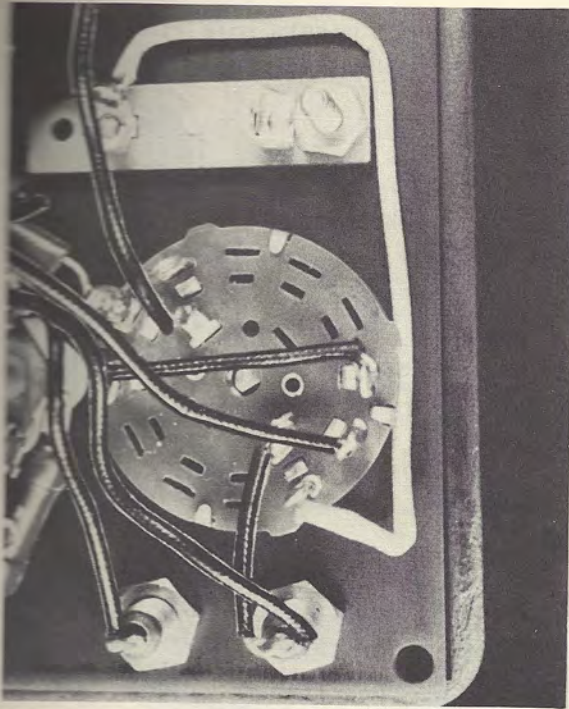


Fig. 12-6

S_2A_3 , and terminal 1 of P_2 .

Procedure.

Step 1. Cut a 1-1/4-inch length of solid pushback wire. Strip 1/4-inch of insulation from each end of the wire.

Step 2. Connect this wire to clip 2 of diode holder 2 and solder the other end to S_2A_3 .

Step 3. Cut a 4-inch length of solid pushback wire, and remove 1/4-inch of insulation from each end.

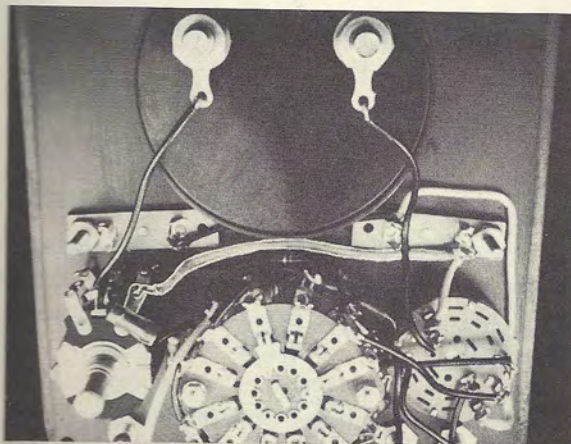


Fig. 12-7

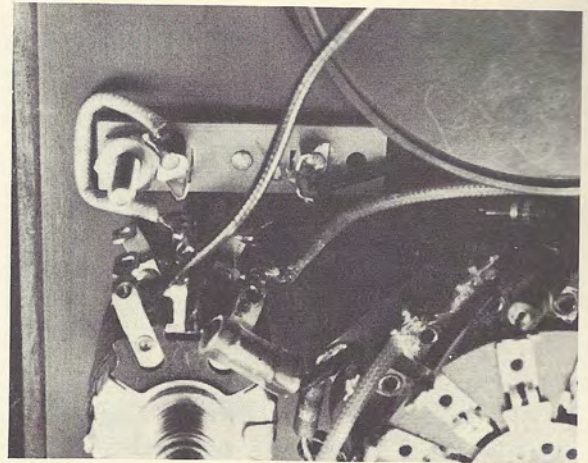


Fig. 12-8

Step 4. Run the wire as shown in Fig. 12-7, and solder one end to terminal 1 of potentiometer P_2 .

Step 5. Solder the other end to clip 2 of diode holder 2. Make sure that you solder the other connection to clip 2 at the same time.

JOB 12-5

To connect clip 1 of diode holder 1 to terminal 2 of potentiometer P_2 .

Procedure.

Step 1. Cut a 2-inch piece of solid pushback wire. Strip 1/4-inch of insulation from each end.

Step 2. Connect one end of the wire to clip 1 of diode holder 1. Solder this connection.

Step 3. Run the wire as shown in Fig. 12-8 and solder it to terminal 2 of potentiometer P_1 . If necessary, unsolder the previously made connection before doing this step.

JOB 12-6

To insert the crystal diodes in their holders.

Procedure.

Step 1. The crystal diodes you received

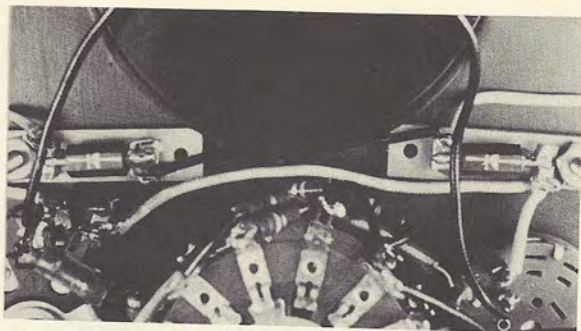


Fig. 12-9

in Kit 6 are identical. With cutting pliers, clip the pigtails off the terminals on both ends of both diodes.

Step 2. Insert the diodes in their holders so that the arrows point in the direction shown in Fig. 12-9.

JOB 12-7

To connect capacitor C_1 between jacks J_2 and J_3 .

Procedure.

Step 1. Apply the tip of your hot soldering iron to the soldered joint on jack J_2 . When the solder is melted, insert the tip of an awl or scribe into the soldering lug of the jack so that you can make room for inserting one of the tinned leads of the capacitor.

Step 2. Center the capacitor between J_2 and J_3 , as shown in Fig. 12-10, with one capacitor lead inserted in the lug of J_2 and the other in the lug of J_3 .

Step 3. Make a good tight joint at each



lug, remove the excess wire with your cutting pliers, and solder each connection.

Discussion. You have just completed the assembly of the a-c section of your multimeter. The object of the next part of this lesson is to calibrate your meter.

JOB 12-8

To calibrate the a-c section of your multimeter.

Procedure.

Step 1. Check with your local electric company to determine *exactly* how much voltage is being supplied to the outlet plugs in your home. The voltage will probably be between 110 and 120 volts.

Step 2. Insert the black test lead into the black pin jack of your multimeter and insert the red test lead into the red pin jack.

Step 3. Turn the FUNCTION switch on your meter to AC position and the RANGE switch to the 300 VAC position.

Step 4. One at a time, insert the test prods into a convenient a-c outlet, as shown in Fig. 12-11.

Step 5. Carefully adjust potentiometer P_2 until the reading on your meter scale is exactly the same as the value of the voltage coming from your outlet (the value you learned from the electric power company).

Step 6. Remove the test leads from the a-c outlet and your meter.

Discussion. You have just calibrated the a-c section of your meter. You will not need to calibrate this part of your meter again until you replace a crystal diode or some other part of your meter.

Now that you have assembled and calibrated your meter, let us discuss the purpose of the parts in the a-c section. When you as-

are sure that you understand the theory of electromagnetic induction and transformer action, do these experiments. If something comes up that puzzles you while you are performing an experiment, do not hesitate to go back to the theory lessons for the answer.

In order to perform the experiments in the first part of this lesson, it will be necessary to remove the meter from the multimeter. This is done in the following manner:

Step 1. Unscrew the four screws that hold the meter panel to the meter case.

Step 2. Remove the four meter-mounting nuts and lock washers that hold the meter to the panel. Free the two diode holders from the meter mounting screws.

Step 3. Loosen the hex nut that holds the soldering lug to the positive terminal of the meter. Do the same for the nut that holds the soldering lug to the negative terminal.

Step 4. Carefully slip the meter free from the soldering lugs and the four mounting holes in the panel, and place it carefully on your bench.

Step 5. Place the meter-mounting nuts and lock washers, together with the panel screws, in the bottom of the multimeter case where you can find them when you need them. Replace the multimeter panel on top of the case without screwing it to one side for your use later on.

Warning: While the meter is disconnected from the multimeter, do not use it for any purpose except as called for by the instructions that follow.

EQUIPMENT NEEDED

1. One 40-penny nail
2. Magnet wire
3. Two bar magnets

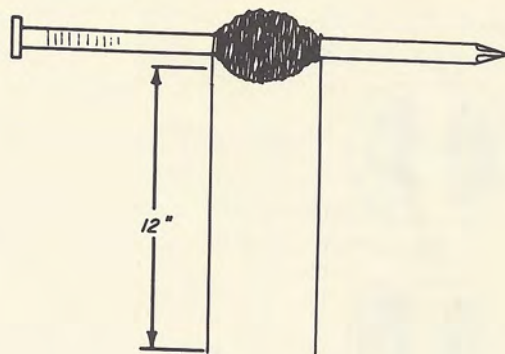


Fig. 12-12

4. Multimeter

EXPERIMENT 12-1

To induce an emf in a coil of wire by causing a magnet to be moved so that the lines of force (flux) of its field cut across the coil's windings.

Procedure.

Step 1. Wind 200 turns of magnet wire on the 40-penny nail. Try to make the turns as

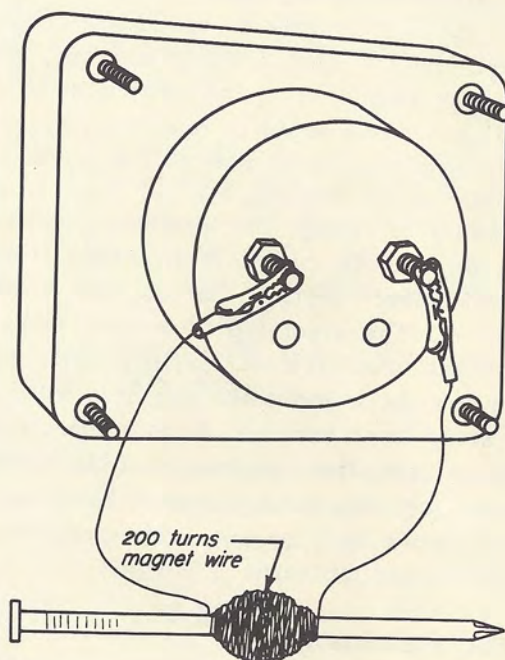


Fig. 12-13

close together as you can. Leave 12 inches of free wire at each end of the nail, as shown in Fig. 12-12.

Step 2. Unsolder the alligator clips from the 4.5-volt battery that you last used in Experiment Lesson 9. Solder one clip to each end of the coil you have just wound.

Step 3. Clip one end of your coil to the positive terminal of the meter and the other end to the negative terminal, as shown in Fig. 12-13.

Step 4. Hold a bar magnet at the end near the North pole of the magnet, as shown in Fig. 12-14a. Hold the North pole close to one end of the coil wound on the nail, as

shown in Fig. 12-14b. Then slowly move the magnet to the other end of the coil, using a steady, even motion. (Do not jerk the magnet.) As you do this, watch the meter needle. Notice the direction in which the needle moves.

Step 5. Move the magnet slowly in the opposite direction so that it goes back to its first position over the coil, as shown in Fig. 12-14c. As you do this, notice once again the direction of the needle's movement.

Step 6. Repeat Steps 4 and 5, using the South pole of the magnet instead of the North pole. In each case, observe carefully the direction in which the meter needle moves. Compare the direction of movement with the direction you noticed in Steps 4 and 5.

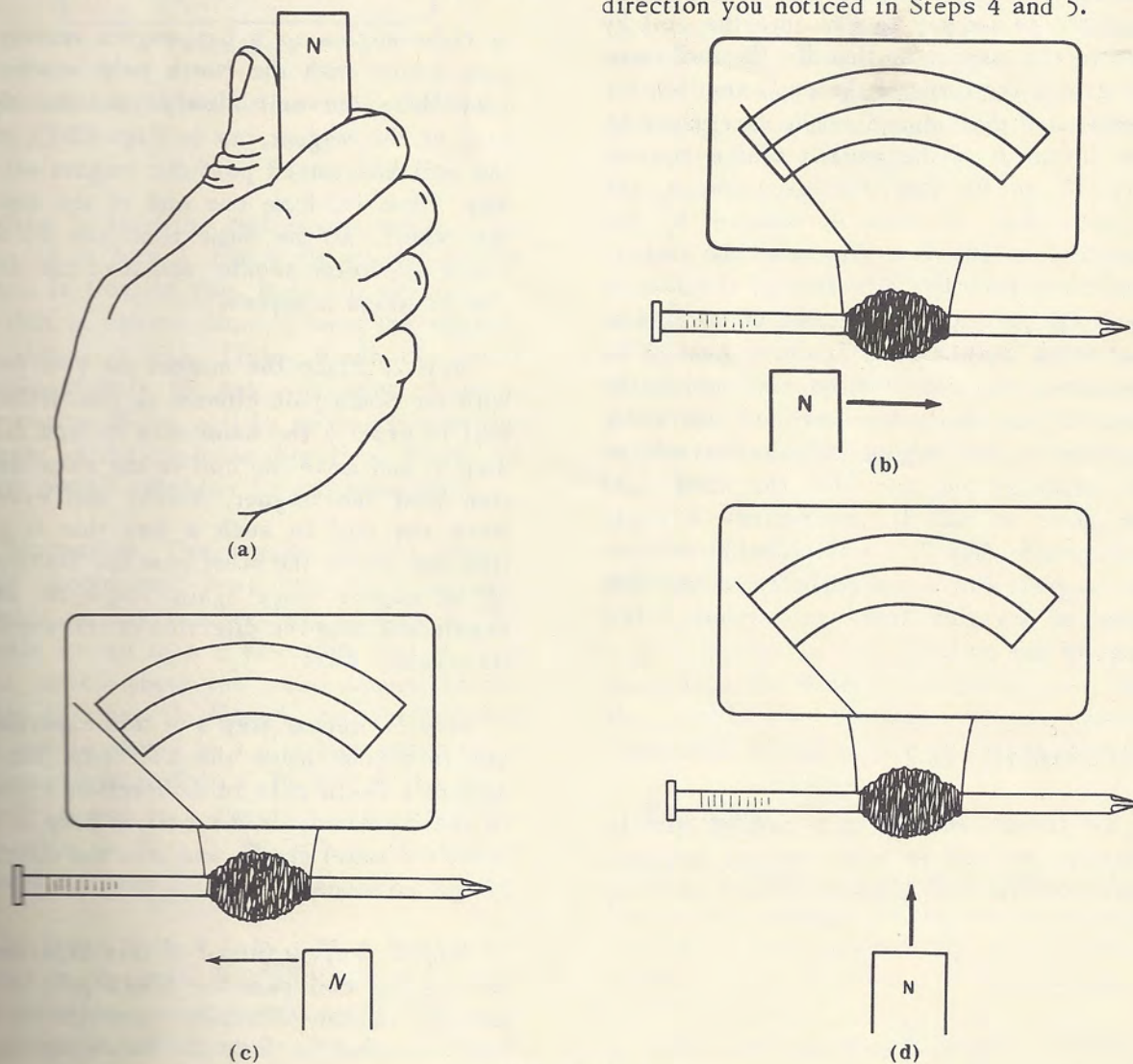


Fig. 12-14

Step 7. Place the magnet in the position shown in Fig. 12-14d and then slowly move it in the direction shown by the arrow. As you do this, watch the meter needle carefully for any signs of movement.

Discussion. If you followed all of the directions given in Experiment 12-1, you found that in Step 4 the meter needle moved slightly either above or below zero. In Step 5, the needle moved in a direction opposite to its movement in Steps 4 and 5. As for Step 7, there was little or no movement at all of the meter needle.

Let us see what we may learn from these findings. Steps 4 and 5 prove that it is possible to induce an emf into the coil by moving the magnet so that its lines of force cut across the turns of the coil, and that the direction of the induced emf is determined by the direction of the motion of the magnet. Step 6 shows that the direction of the induced emf is also determined by the direction of the flux (because the change was made from the direction of the flux at the North pole to the direction of the flux at the South pole). Step 7 shows that it is necessary for the flux to cut across the turns of the coil, because, in this case, you moved the magnet in the direction of the windings and saw that the needle did not move at all. If you noticed a slight movement in Step 7, it was probably because the magnet was moved in such a way that some of its flux lines cut across a few turns of the coil.

EXPERIMENT 12-2

To induce an emf in a coil of wire by causing the coil to move so that its turns cut across the flux lines of a fixed magnetic field.

Procedure.

Step 1. Use the coil that you made in Experiment 12-1. Hold the coil at one end,

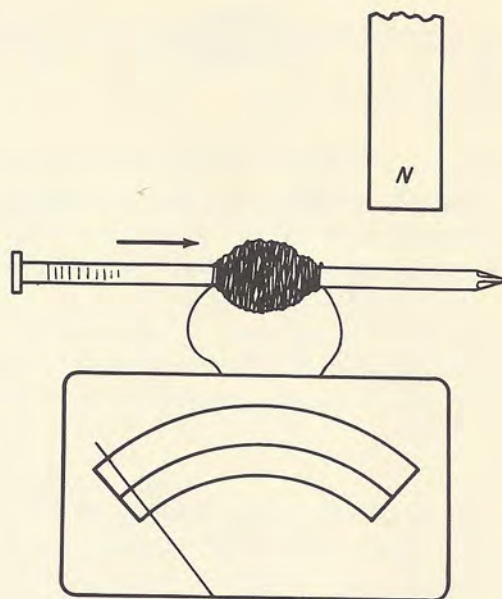


Fig. 12-15

at right angles to a bar magnet resting on your bench with the North pole nearest to you. Move the coil slowly past the North pole of the magnet, as in Fig. 12-15, until the coil has moved past the magnet all the way, (that is, from one end of the coil to the other). At the same time you do this, watch the meter needle and note the direction in which it moves.

Step 2. Place the magnet on your bench with the South pole closest to you. Hold the coil in exactly the same way as you did in Step 1, and move the coil in the same direction past the magnet, slowly and evenly. Move the coil in such a way that it goes from one end to the other past the South pole of the magnet. Once again, watch the meter needle and note the direction of the needle's movement.

Step 3. Repeat Step 1 of this experiment, but this time move the coil past the bar magnet's North pole in a direction opposite to the movement of the coil in Step 1. Observe the meter needle and note the direction of the movement.

Step 4. Repeat Step 2 of this experiment, moving the coil past the South pole of the magnet in the direction opposite to the coil's motion in Step 2. Watch the meter needle as you do this, and compare the

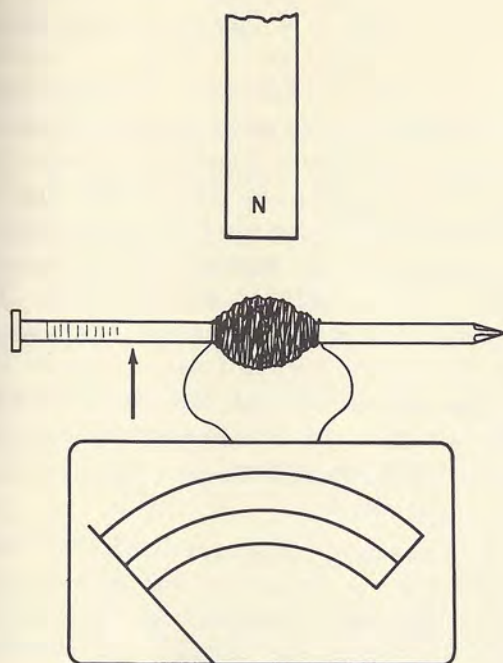


Fig. 12-16

way in which the needle moves to the way it moved in Step 2.

Step 5. Hold the coil at one end, just as you did in Step 1. Place the magnet on the bench in front of you. Move the coil slowly so that it passes directly over the magnet, as shown in Fig. 12-16. Watch the meter needle closely for any movement. Reverse the motion of the coil by moving it over the magnet in the opposite direction. Watch the meter needle carefully for any movement.

Discussion. The results of this experiment should have been very much like the results of Experiment 12-1. In Step 1, the needle moved in one direction, and in Step 2 it moved about the same amount in the other direction. In Step 3, you noticed that the needle moved in a direction opposite to its movement in Step 1. In Step 4, the meter needle moved in a direction opposite to its movement in Step 2. In Step 5, the needle should not have moved at all.

In Steps 1 to 4, why was a current induced in the coil? Why did it flow through the meter and cause a movement? Just as it is possible to induce an emf into the coil by moving a magnet in such a way that its

flux lines cut across the turns of the coil, it is also possible to induce an emf into the coil by moving the coil instead of the magnet. Once again we see that the direction of the meter needle's movement depends upon the direction of the flux lines; the meter needle changed its direction when the coil moved past the South pole of the magnet instead of the North pole. The needle moved in one direction when the coil was moved from right to left.

Does it make any difference whether the magnet moves or the coil moves when you wish to induce an emf into the coil? You proved in Experiments 12-1 and 12-2 that it doesn't make any difference which one moves. Two things are necessary in order to induce an emf into a coil. First of all, there must be movement between the magnet and the coil. We refer to this as *relative motion* between a coil and a magnetic field. Secondly, the motion must be in such a way that the turns of the coil are cut by the flux lines of the magnetic field.

In Experiments 12-1 and 12-2, you were interested in the direction of the meter needle's movement, rather than in the amount of movement of the needle. Now let us see what determines the relative *amount* of emf induced. Remember that the greater the needle swing, the greater is the induced voltage.

EXPERIMENT 12-3

To induce an emf into a coil of wire using first the field of one bar magnet, then the field of two bar magnets, and compare the amount of emf produced.

Procedure.

Step 1. Repeat Step 4 of Experiment 12-1. Record the readings. (If the needle moves to the left of zero, reverse the meter connections.)

Step 2. Hold two bar magnets together, with like poles facing the same way. With

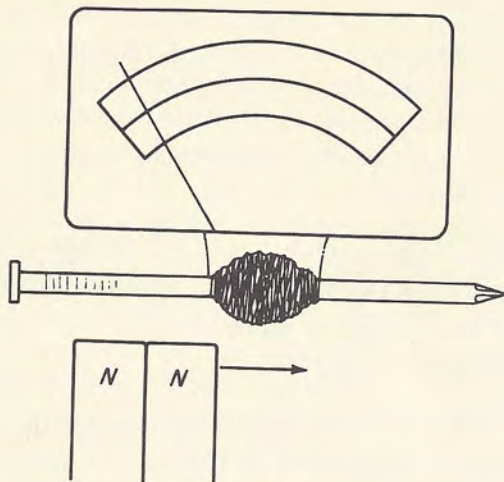


Fig. 12-17

the north poles nearest the coil, as in Fig. 12-17, slowly move both magnets from one side of the coil to the other, using a steady motion. Compare this reading with the reading you obtained in Step 1.

Step 3. Repeat Steps 1 and 2, using the south poles in each case. When you do this with the two magnets, be sure that like poles are placed side by side. Compare the amounts of emf produced in each case.

Step 4. Place one bar magnet on the bench, with the north pole near you. Repeat Step 1 of Experiment 12-2. (If the meter needle moves to the left of zero, place the opposite pole of the bar magnet in a position nearest to you.) Write down the reading.

Step 5. Hold the other bar magnet next to the first one, so that both north poles are near you. Starting at one end of the coil, as shown in Fig. 12-18, move the coil past the two magnets slowly and evenly, until the other end of the coil passes the magnets. Write down the distance that the needle moves. Compare the result with the amount of emf obtained in Step 4.

Step 6. Repeat Steps 4 and 5 with the other pole of first one magnet nearest to you, and then both magnets. Compare the amounts of emf induced in each case.

Discussion. If you followed the directions carefully, the amount of emf that was

induced in Step 2 of this experiment should have been twice as much as the amount found in Step 1. Likewise, Step 5 should have shown that the reading you obtained on the meter was about double the amount you put down for Step 4. The reason for the differences in the amounts of emf induced is the increase in the strength of the magnetic field due to the addition of a bar magnet. The magnetic field of two bar magnets is twice as great as that of one bar magnet; that is, two bar magnets placed with like poles touching have about twice the number of lines of force as one bar magnet.

As a result of this experiment, you have proved that the amount of emf induced in a coil depends on the strength of the magnetic field. Therefore, the stronger the magnetic field, the greater will be the emf that is induced; the induced emf will be greater if more lines of force cut across the turns of the coil. The induced emf will be smaller if fewer lines of force cut across the turns of the coil.

EXPERIMENT 12-4

To induce an emf in a coil of wire by having the flux lines cut the turns of the

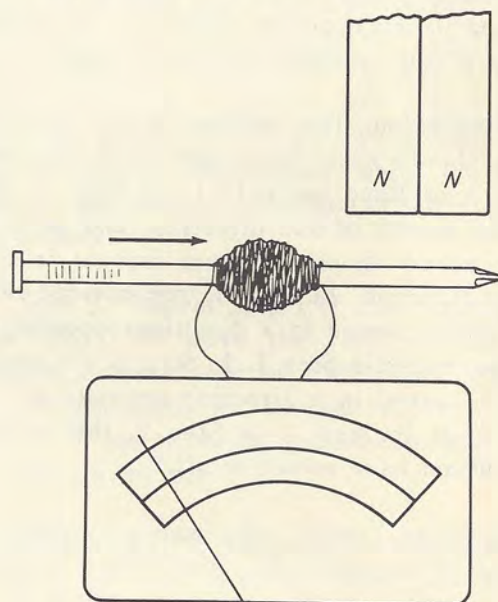


Fig. 12-18

coil slowly, then rapidly, and compare the amount of emf produced.

Procedure. In this experiment, it is very important that you try to judge the speed of movement of the magnet slowly. (Try to remember *how* slowly you actually move it.) In case the directions call for moving the magnet rapidly, be sure that you move it faster than before, and try to make a mental note of *how* fast you move it.

Step 1. Repeat Step 1 of Experiment 12-3, using the pole of the magnet that caused the meter needle to move to the right. Move the magnet *slowly*. Write down the meter reading.

Step 2. Do Step 1 of this experiment again, but this time move the magnet *rapidly*. Write down the meter reading, and compare it with the reading in Step 1.

Step 3. Repeat Step 1, using two bar magnets with like poles held together. Write down the result.

Step 4. Repeat Step 2, using two bar magnets. Write down the result, and compare it with the result obtained in Step 3.

Step 5. Now do Steps 1 to 4 over again, this time using the other pole of the magnets. Write down the amount of emf induced each time, and compare all the results.

Step 6. Repeat all the steps of this experiment, but move the coil past the magnet, as you did in Experiment 12-2.

Discussion. When you performed this experiment, you found that it was very important to follow all directions carefully, because the speed of movement of the magnet or the coil determines the amount of emf that is induced.

In Step 1, you induced a certain amount of emf in the coil, and made a note of it. Step 2 gave you a greater amount of emf, because you moved the magnet faster. If you moved the magnet twice as fast as you did in Step

1, you obtained twice as much induced emf. In case you moved it more than twice as fast, the amount of emf induced was more than double the amount that you noted first.

The other steps of this experiment produced similar results. They proved that the amount of emf induced in a coil also depends upon the *speed* at which the turns of the coil are cut by lines of force (speed of motion). The greater the speed, the greater is the amount of emf induced.

EXPERIMENT 12-5

To induce an emf in a coil of 200 turns of wire, then in a coil of 400 turns of wire, and compare the amount of emf produced.

Procedure.

Step 1. Repeat Step 1 of Experiment 12-3. Record the reading of the meter needle.

Step 2. Unsolder the alligator clip from the outer lead of the coil wound on the nail. Solder this lead to the free end of the spool of magnet wire. Wind 200 turns more on the nail (making 400 turns in all). Be sure to leave 12 inches of free wire to use as a lead.

Step 3. Solder the alligator clip to the free end of the 400-turn coil that you just made.

Step 4. Clip one end of the coil to the positive terminal of the meter movement and the other end to the negative terminal.

Step 5. Repeat Step 1 of this experiment, using the 400-turn coil. Compare the result obtained with the amount of emf induced in Step 1. (If the meter needle moves to the left of zero, reverse the meter connection.)

Step 6. In order to review the facts that you observed in the other experiments you performed in this lesson, compare the results

you get with *slow* motion against *fast* motion, and with *one* magnet against *two* magnets.

Discussion. If the 400-turn coil that you made was prepared carefully, you saw that the amount of emf induced into it was about twice as great as the amount you induced into the 200-turn coil. This proves that the amount of emf induced in a coil also depends upon the number of turns of wire. The more turns of wire in the coil, the more will be the amount of the induced emf.

Now you are ready for a summary of all the things that this lesson has proven to you. First of all, an emf is induced in a coil of wire if there is a relative motion between the coil and a magnetic field, and if the lines of force cut across the turns of the coil. Secondly, the strength of the induced emf depends upon:

1. The strength of the magnetic field (the number of flux lines).
2. The speed of cutting (the speed of the relative motion between the coil and the magnetic field).
3. The number of turns of wire in the coil.

In all of these experiments, the magnetic field has been a *fixed* one. The only change you made was to use two bar magnets instead of one, but while the experiment was being performed, the number of lines of force that cut the turns of the coil remained the same.

Later you will study the effect of a *changing* magnetic field on the coil of wire, when there is a relative motion between them.
